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Access to Handouts of Presentation Slides During Lecture: Consequences for Learning

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SUMMARY

Teachers often lecture with presentation software such as Microsoft PowerPoint; however, little research has examined the effects of this new technology on learning. One issue that arises is whether or not to give students copies of the lecture slides, and if so when. A survey documented that students prefer to receive lecture slides before class, whereas instructors were less pronounced in their preferences. Two experiments examined whether having handouts of the slides facilitated encoding of science lectures. Having access to handouts of the slides during lecture was associated with a number of benefits: less note-taking (studies 1 and 2), less time needed to prepare for a final test (study 1), and better performance on the final test (study 2). Overall, receiving handouts before lecture helped efficient encoding of the lecture. Copyright © 2009 John Wiley & Sons, Ltd.

New technology is often integrated into the classroom. One recent trend is to lecture using Microsoft PowerPoint or other presentation software, as opposed to relying on overhead transparencies or the chalkboard. Like all instructional aids, there are pros and cons associated with the use of electronic presentations, and the curious teacher can easily find numerous lists of do's and don'ts for using the technology (e.g. Quible, 2002; Simpson, Pollacia, Speers, Willis, & Tarver, 2003). It is difficult to assess what effects, if any, software like PowerPoint has on learning, as any evaluation is specific to the particular slides used and instruction provided, and depends on the nature of the control group. What is clearer, though, is that students generally have favourable reactions to the use of PowerPoint and other electronic presentations in the classroom (e.g. Atkins-Sayre, Hopkins, & Mohundro, 1998; Frey & Birnbaum, 2002; Nicholson, 2002; Simpson et al., 2003). Students endorse survey items such as '. . .PowerPoint is more interesting than presentations of material in the more traditional lecture formats' (Mantei, 2000).

While student preferences do not always map onto the most educationally beneficial methods, the combination of student liking and the ease of obtaining PowerPoint slides (e.g. from publishers) make it seem likely that the electronic presentation trend will continue. The use of this technology in the classroom raises many questions, some of them intriguing to cognitive psychologists because basic research allows for two opposing predictions. Of interest here is what seems to be a simple question about how to use such software in the classroom: namely, when (if at all) to give students copies of the slides. This issue arises because instructors often have the option to distribute lecture slides *before*

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class, either via a class website or through an online course management system such as Blackboard™. Before we review the relevant cognitive psychology literatures (which can be used to motivate two different solutions to this problem), we report briefly the results of a survey conducted to get a sense of student and instructor preferences.

Because we could not find any survey data on student preferences for *when* PowerPoint slides should be distributed, we asked 50 Duke undergraduates for their opinions on this topic. We also surveyed 35 college instructors. Each survey contained illustrations of two PowerPoint slides from a science lecture (downloaded from http://www.wlap.org/browser.php?ID=umich-smp), and respondents were informed that the slides were a sample of the ones used in a longer lecture. Students were asked 'If you were attending this class, what would be your preference regarding handouts of the PowerPoint slides (Please check only ONE): receive them before lecture, receive them after lecture, or never receive them'. Respondents then answered the question 'Why is this your preference'? The instructors received the same surveys, except that they read 'If you were teaching this class...' and were asked about distributing the slides.

Students and instructors differed in their slides preferences, X^2 $(2) = 7.46$, $p < .03$. Overwhelmingly, students preferred to receive the slides *before* lecture (74%) as opposed to *after* lecture (22%) or never (4%). While faculty members also said they would distribute the slides *before* lecture (50%), their preference was less pronounced. Twenty-one per cent of instructors said they would *never* distribute the slides, and 29% preferred to distribute the slides after the lecture.

Two raters independently classified the reasons given for slide preferences, and they agreed on 92% of judgments. A third coder (the second author) resolved all discrepancies. The most common reason for wanting the slides before class was that it would help note-taking (63%). In addition, respondents felt receiving/distributing the slides before class would make it easier to understand lecture (44%) and help students prepare for class (43%). Fifteen per cent said it would reduce distraction during the lecture, and 9% claimed it would help students to organize and structure the lecture.

When a preference was stated for receiving/distributing slides *after* lecture, the most common reason was that the slides would be helpful for later review (38%). These subjects also claimed distributing the slides later would allow note-taking (33%) and that note-taking was an important learning behaviour (14%). There was a concern that having the slides during the lecture would be distracting; 24% claimed the slides would be too confusing until after the lecture was complete, 29% said students wouldn't pay attention in class if they had the slides, and 14% said students would be sidetracked from what the professor was saying.

So how do student and faculty intuitions line up with what we know from cognitive psychology? First, the student preference for receiving the slides before class is not without merit. There are reasons to believe that receiving the slides before class will help students to process the lecture. We call this the hypothesis of *Efficient Encoding*, which suggests that the slides should be distributed prior to class. However, research on *Desirable Difficulties* allows the opposite prediction, as oftentimes conditions that make learning more difficult can have long-term positive consequences. Below we briefly review the literatures supporting these two opposing predictions.

We begin with the hypothesis of *Efficient Encoding*, which suggests that the slides should be distributed prior to class. In many classes, the student must simultaneously attend to, comprehend, and take notes on a lecture accompanied by an electronic presentation. In the terms of cognitive psychology, this is a dual-task situation, and it is well known that

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dividing attention during encoding has negative consequences for memory (e.g. Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Mulligan, 1998). Students with access to slide handouts would still have to attend to and comprehend the lecture, and take some notes (as presumably not everything the instructor would say would be printed on the slides). However, the amount of note-taking would be reduced, thus allowing more attention to be devoted to listening to and comprehending the lecture. While the literature on note-taking and learning is mixed, several studies have shown that learning improves when students do not have to take notes, suggesting that a reduction in note-taking should benefit memory (Ash & Carlton, 1953; Peters, 1972). In addition, the nature of the processing underlying note-taking might change. Specifically, note-taking would shift from *copying* the content of the slides to notes *explaining* the slides, which might reflect a shift to deeper processing, which would have positive consequences for memory (Craik & Lockhart, 1972).

In contrast, research on *Desirable Difficulties* suggests that slide handouts should be distributed after class. As already noted, what students like may not be what is best for them, and research on *Desirable Difficulties* suggests that more difficult learning can have long-term advantages. For example, long-term retention is generally better after testing than re-studying (e.g. Glover, 1989; Roediger & Karpicke, 2006), after answering short-answer questions rather than multiple-choice questions (Kang, McDermott, & Roediger, 2007) and following spaced practice rather than massed (e.g. Melton, 1970; Dempster, 1988). Although these encoding conditions are more difficult, they are more similar to test conditions: tests occur after a delay (hence the benefit of spaced practice) and require retrieval (hence the benefits of testing, especially with short-answer questions). In other words, if the encoding task 'demands other kinds of information processing—such as retrieval practice—that are also needed for retention performance, then such added difficulty can be expected to enhance retention performance' (Schmidt & Bjork, 1992, p. 210). From this perspective, note-taking should *not* be classified as a shallow processing task. Rather, an argument can be made that note-taking transforms the passive listener into an active recorder of the lecture, potentially yielding the same kind of mnemonic benefit observed in laboratory studies in which subjects generate (Slamecka & Graf, 1978) or enact to-be-remembered material (Engelkamp, 1998).

To test these two hypotheses, we experimentally manipulated whether or not handouts were available during lecture in order to capture any consequences for note-taking during lecture, post-encoding review, and test. Subjects watched four videos of an instructor teaching science with presentation software; while subjects could see the slides in all lectures, they only had access to paper handouts of the slides while watching two of the four lectures. Of interest were the implications of having the handouts during lecture, both for note-taking and for later performance on a general knowledge test.

We also manipulated the timing of the final test in Experiment 1. It was important to examine both immediate and delayed tests because desirable difficulties sometimes have their impact on delayed (but not immediate) tests. For example, while cramming (massed study) is a bad strategy for accumulating long-term knowledge, it is a reasonable strategy for an immediate test (Austin, 1921; Glover, 1989). One possibility was that the easier encoding (with the handouts available for note-taking) would help on an immediate test, but that any benefit would not persist to a final test. In other words, any benefit from the more difficult encoding (the handouts absent condition) might only show up on a delayed test. Thus we tested subjects on their knowledge of the science videos after a very short delay (12 minutes) or after a delay of 1 week.

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Finally, we manipulated whether or not the lectures were reviewed prior to the final tests. To mimic the real-life situation in which professors often distribute the PowerPoint slides *after* lecture, when a lecture was reviewed subjects had access to both their original notes and the handout of the PowerPoint slides. The question was whether review behaviours might differ as a function of whether the lecture had been watched with the handouts available. Receiving the handouts for the first time during the review period would require the integration of one's course notes with the handout of the slides, something that would take effort—and it is possible that this would be a desirable difficulty. In general, reorganization during a review period is considered to involve deep processing and have positive consequences for memory (e.g. Shimmerick & Nolan, 1976). The point for present purposes is that review is more likely to involve reorganizing notes in the condition in which the handouts were absent during encoding. In contrast, when handouts of the slides are available during lecture, subjects presumably will take their notes on the handout, potentially simplifying review.

In summary, subjects in two experiments watched four science videos, each of which featured a lecturer who referenced PowerPoint slides. Subjects were instructed to take notes on all four videos but during the encoding phase they received handouts of the slides for only two of the four videos. After watching the lectures, subjects had the opportunity to review their lecture notes and the slide handouts (Subjects reviewed two of the four lectures in Experiment 1, and all four lectures in Experiment 2). Of interest was whether performance on a general knowledge test would depend on whether the handouts had been available during lecture-watching. In Experiment 1, this final test involved short-answer and multiple-choice questions, and half the subjects were tested immediately and half returned after 1 week to take the test (to be clear, subjects in the delayed condition reviewed their notes in the second session, not the first). In Experiment 2, all testing was immediate and involved either short answer or free recall format.

The Efficient Encoding Hypothesis predicts better performance on the final tests corresponding to the lectures watched with the slide handouts available. The Desirable Difficulties Hypothesis predicts the opposite, and specifically suggests performance on the delayed test should be best for the condition in which handouts were received for the first time during the review period.

EXPERIMENT 1

Method

Participants

Forty-eight Duke University students participated in the study. Subjects received course credit or $20 for their participation. Subjects were non-science majors.

Materials

Phase I (the lecture phase) materials consisted of excerpts from four videos from the University of Michigan's Saturday Morning Physics lecture series. Each lecture depicted a speaker lecturing on a different physics topic: cosmology (Freese, 2003), DNA (Blumberg, 2003), subatomic matter (Miller, 2003), and superconductors (Bernstein, 2003). The excerpts averaged 12.56 minutes in length and each contained references to eight PowerPoint slides, which were visible in the videos, just as they were to the real audience.

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In the experiment, handouts contained three slides per page and were distributed before two of the lectures. Lectures were viewed in two different orders, counterbalanced across subjects.

Phase II and IV (the first and second filler tasks) materials consisted of visuo-spatial brainteasers in paper-and-pencil format.

Phase III (the review phase) materials consisted of all notes from the lecture phase for two of the lectures (one from the Handouts Present condition and one from Handouts Absent). That is, subjects reviewed the materials for two lectures and did not review anything for the other two. When a lecture was reviewed, subjects always received the corresponding PowerPoint handout. For lectures in the Handout Present condition, subjects received their original (likely annotated) PowerPoint handouts, and any additional notes they took during the viewing phase. For lectures in the Handout Absent condition, subjects received the PowerPoint handouts for the first time, in addition to their lecture notes. Which lectures were reviewed was counterbalanced across subjects.

Phase V (the test phase) materials were 4 tests, one pertaining to each lecture. Each test consisted of 10 questions (seven multiple-choice plus three short-answer) presented on the computer; thus, there were 40 questions total. The first portion of each test consisted of the multiple-choice questions, and the second part consisted of the short-answer questions (see Appendix). Within each multiple-choice and short-answer question section, questions were presented in random order using Medialab and DirectRT software (Jarvis, 2004a, b). Lectures were tested in the same order as they had been viewed in phase I.

Design

The study had a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Review with Handouts: Yes or No) x 2 (Delay: 12 minutes or 1 week) mixed design. Delay was the only between-subjects variable; all other variables were manipulated within-subjects to maximize power. Thus each subject watched two videos with handouts and two without handouts. He or she reviewed one of the two lectures originally viewed with the handouts, and one of the lectures for which handouts had not been available. Order of the videos, the presence of handouts during lecture, and review condition were counterbalanced across subjects. Dependent measures were number of words recorded during the lecture (note-taking behaviour), amount of time spent reviewing each lecture before the test (review behaviour), and proportion correct on the final tests (test behaviour).

Procedure

Each subject was seated at a computer, and all instructions were presented visually on the computer screen. As shown in Figure 1, the first phase involved watching four videos of science lectures and taking notes. Subjects were told that they would watch four short science lectures on which they would later be tested, and that they should behave as if they were preparing for and taking real science exams. They were informed that they would have a chance to review two of the four lectures before the test.

Before each lecture, the computer screen informed subjects what materials they would need for the upcoming lecture. For two of the four lectures, subjects were prompted to have a clipboard, blank paper and a blue pen. For the other lectures, subjects received handouts of the relevant PowerPoint slides as well as the clipboard, blank paper and blue pen. After each video clip finished, subjects returned their materials to the experimenter. That is, during any one lecture, subjects only had in their possession the materials relevant to that particular lecture.

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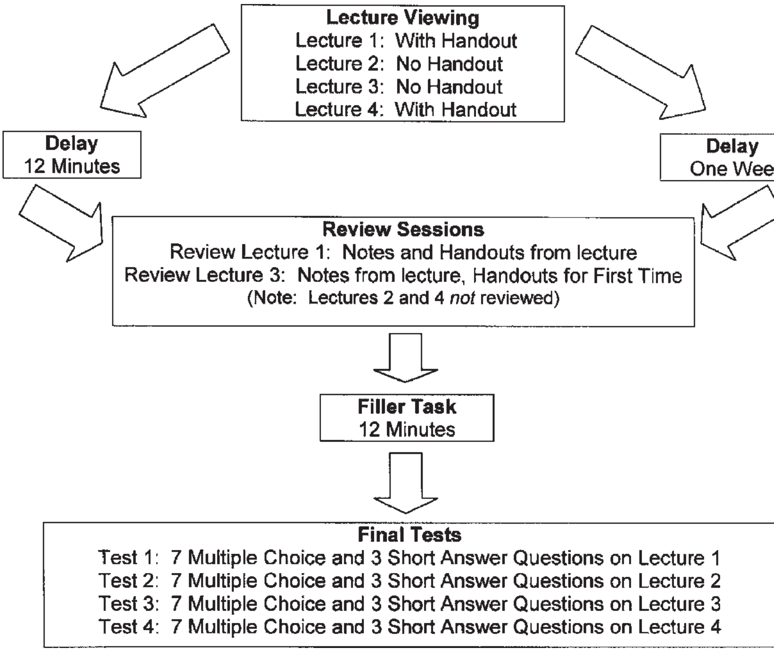

Figure 1. Procedure of Experiment 1. Subjects watched and took notes on four science lectures; immediately before two of the four lectures, subjects received handouts depicting the PowerPoint slides from the lecture. One-half of subjects reviewed after a 12-minute delay and one-half after 1 week. Each subject reviewed two lectures, one that had been watched with handouts and one watched without handouts. During review, subjects always received their original notes and the PowerPoint handouts. After a filler task, subjects took a test on each of the four lectures. Order of the lectures, which lectures were paired with handouts, and which lectures were reviewed were counterbalanced across subjects

Subjects watched the four video lectures consecutively. Subjects were not allowed to pause the video or to re-watch portions; all subjects watched exactly the same video. After the lectures, subjects in the delay condition were dismissed from the experiment. Subjects in the 12-minute delay condition worked on unrelated visuo-spatial puzzles for 12 minutes.

After the filler task (or after 1 week for *delay* subjects), subjects were given the chance to review the content of two of the four lectures. This review session was blocked by topic; subjects reviewed one target lecture at a time, beginning with whichever of the two target lectures had been viewed earlier in the experiment. The experimenter gave the student their lecture notes and the PowerPoint handouts for the first to-be-reviewed topic. They were also given a red pen (rather than the blue pen used in the lecture phase) with which to take additional notes if so desired. They were instructed to press the space bar when they were finished reviewing and to return their materials to the experimenter. After subjects finished reviewing the first set of materials, they received the second set and repeated the process for the second target lecture. Subjects were allowed as long as they wished to review each lecture, and the amount of time spent reviewing was recorded.

Following the review phase, subjects completed a second filler task, which consisted of working on visuo-spatial puzzles for another 12 minutes.

In phase V, subjects took four tests, one on each lecture. For each lecture, subjects answered seven multiple-choice questions and three short-answer questions; we included a

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mix of questions to parallel how exams often contain a mix of question-types. Testing was blocked by lecture, in the same order as the lectures were seen in phase I. In total, subjects answered 40 questions, 10 pertaining to each lecture. They were then debriefed and thanked for their participation.

Results

Unless otherwise noted, results were significant at the .05 alpha level.

Lecture behaviour

As expected, note-taking during the lecture depended on whether or not handouts of the slides were available in addition to blank paper for note-taking. That is, a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Delay length: 12 minutes or 1 week) x 2 (Review with Handouts: Yes or No) ANOVA computed on mean number of words written during lecture viewing yielded only one significant result: a main effect of whether handouts were available during the lecture, $F(146) = 100.86$, $MSE = 1394.18$, $\eta_p^2 = .69$. On average subjects wrote fewer words during the two lectures accompanied by handouts of the PowerPoint slides ($M = 49.1$) than for the two lectures for which only blank paper was available for note-taking ($M = 103.2$), $t(47) = 10.12$, $SEM = 5.35$. In other words, when the handouts were unavailable, subjects wrote down twice as many words as they did when they had access to the handouts during the lecture.

A second analysis examined the content of the notes, to understand why so many more words were written when the slide handouts were unavailable. Specifically, we analysed how much of the notes could be defined as 'slide information.' Slide information was defined as repeating exact words from the slides and words that were synonymous with ideas from the slides. Subjects also took notes on lecture content that was not duplicated in the PowerPoint slides; these types of notes were *not* considered to reflect slide information. Two coders counted the number of words reflecting slide content; because the counts were highly correlated ($r = .93$), the counts were averaged for analysis. The prior analysis was re-done with content (slide versus non-slide) added as a factor, yielding a 2 (Content: Slide or Non-slide) x 2 (Presence of handouts during lecture: Present or Absent) x 2 (Delay length: 12 minutes or 1 week) x 2 (Review with Handouts: Yes or No) ANOVA. In addition to the main effect of handout condition, two new effects were observed. First, there was a main effect of content, whereby the notes included more slide information than non-slide information, $F(146) = 11.42$, $MSE = 1192.54$, $\eta_p^2 = .20$. This was qualified by an interaction with handout presence, $F(146) = 46.71$, $MSE = 1078.87$, $\eta_p^2 = .50$. Subjects' notes included many more *slide* words for lectures in the Handouts Absent condition ($M = 69.0$) than in the Handouts Present condition ($M = 19.0$), and this difference was significant, $t(47) = 8.90$, $SEM = 5.62$. Recording of non-slide words was similar in two conditions (on average 30.0 when handouts were present and 34.0 when handouts were absent), and this difference was only marginally significant, $t(47) = 1.87$, $SEM = 2.20$, $p > .06$. In short, watching the lecture without access to handouts led to a large increase in copying slide words, and having access to the handouts relieved that burden. However, subjects did not write down more non-slide notes for the lectures watched with handouts, even though they no longer had to copy the slides. In fact, on average their notes included four fewer non-slide words for lectures in the Handouts Present condition as compared to lectures in the Handouts Absent condition. Overall, the difference between lectures in

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quantity of note-taking was driven by the need to copy the slides when handouts were unavailable.

Review habits

Post-lecture review habits differed depending on whether or not handouts of the slides had been available during lecture. That is, a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Delay length: 12 minutes or 1 week) ANOVA computed on mean review time yielded a significant main effect of whether the handouts had been available during lecture, $F(146) = 5.67$, $MSE = .78$, $\eta_p^2 = .11$. Even though subjects had access to the handouts in both review sessions, they spent more time reviewing the lecture that had been watched without the handouts ($M = 2.29$ minutes) than on reviewing the lecture that had been watched with the handout ($M = 1.86$ minutes). Also, as expected, there was a main effect of delay, $F(146) = 4.13$, $MSE = 2.54$, $\eta_p^2 = .08$. When reviewing after one week delay, subjects spent more time reviewing the lectures ($M = 2.40$ minutes) than did subjects in the immediate condition ($M = 1.74$ minutes). However, there was no significant interaction between whether handouts were present during lecture and delay ($F < 1$).

Subjects were given a red pen with which to write additional words during the review period; however, only 12 of the 48 subjects wrote any words in red ink (and these 12 subjects wrote on average only 7.6 words in red ink). Writing additional notes while reviewing a lecture was rare and did not differ as a function of whether the handouts had been available during the lecture ($t < 1$).

Test performance

Each of the four tests contained seven multiple-choice and three short-answer questions. The computer automatically scored multiple-choice answers, awarding 1 point per correct answer and zero points for errors. The computer collected short-answer responses in text files that were labeled only with subject numbers. Two trained undergraduate coders (who were blind to experimental condition) scored each short-answer response; a response was awarded 1 point if correct, ½ point if partially correct, and zero points if incorrect. The coders' scores were moderately correlated ($r = .70$), and a third coder (the second author, who was also condition-blind) resolved all discrepancies. After all discrepancies were resolved, the points from the short-answer questions (up to a maximum of three) and the multiple-choice scores (up to a maximum of seven) were summed and divided by 10, yielding proportion correct scores for each of the four tests. We collapsed over these two kinds of questions because we did not counterbalance for question form (and thus question form and test content were confounded); our intent was to include different types of questions to parallel what teachers often do.

As expected, test performance depended on whether or not the topic being tested had been reviewed. Subjects performed better on tests after reviewing the material ($M = 0.73$) than on tests for which they had not reviewed the relevant material ($M = 0.65$), $F(146) = 9.42$, $MSE = .03$, $\eta_p^2 = .17$. Also as expected, there was a main effect of delay $F(146) = 12.51$, $MSE = .06$, $\eta_p^2 = .21$. Subjects in the immediate condition performed better ($M = 0.75$) than those in the delay condition ($M = 0.63$).

The only significant interaction was between review and delay $F(146) = 7.78$, $MSE = .03$, $\eta_p^2 = .15$. Review was more important when testing was delayed; reviewing the material increased performance by 15% when testing was delayed a week compared to 0.7% when testing was immediate. Importantly, there was no main effect of whether the

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Table 1. Test performance, as a function of whether handouts of presentation slides were present during encoding of the lecture, review condition and delay. Data are from Experiment 1

		Presence of Handouts (during lecture)		
Test Time	Review with Handouts	Handouts Present	Handouts Absent	*M*
Immediate				
	Reviewed	0.76	0.75	0.75
	Not Reviewed	0.75	0.74	0.75
Delayed				
	Reviewed	0.71	0.70	0.71
	Not Reviewed	0.55	0.56	0.55
M		0.69	0.70	

Note. The standard error was 0.03 in the immediate condition and 0.04 in the delayed condition.

handouts had been available during the lectures, nor were any other interactions significant (F's < 1). The complete data breakdown can be seen in Table 1.

Discussion of experiment 1

In Experiment 1, final test performance did not depend upon whether or not the handouts had been available during the lecture. That is, subjects did equally well on test questions about lectures encoded with slide handouts as those encoded without the handouts. However, the availability of handouts during lecture affected subjects' note-taking and review behaviours. When lectures were viewed without access to handouts of the slides, subjects took more notes in an effort to copy down the slides presented in the video. In addition, lectures were reviewed for additional time if they had been watched without the handouts. Thus, performance was equally good on questions tapping material encoded without the handouts, but more effort was expended to do so. In short, encoding the lectures with handouts was more efficient: fewer notes were taken on these lectures and they were reviewed for less time, and these shortcuts did not come at any cost to final test performance.

Experiment 2 was designed to replicate our results, and to examine an additional dependent measure: free recall of the lectures. In Experiment 1, we used a single test score to measure memory for the lectures; this test score was based on seven multiple-choice questions and three short-answer questions.[1] We created a larger set of short-answer questions for Experiment 2, to allow performance on these questions to be compared to overall free recall of the lectures' content. Thus subjects in Experiment 2 answered short-answer questions about two lectures and recalled as much as possible of the other two lectures. Combined, the two conditions allow a strong test of the possibility that additional note-taking (as occurs in the Handouts Absent condition) may have positive memorial consequences for later tests that require generation of answers.

[1]We reported a single test score in Experiment 1, because we did not counterbalance whether facts were tested in multiple-choice versus short answer format. However, a closer examination of the data revealed that numerically the pattern was different for the two types of questions: performance on the multiple-choice questions was higher in the handouts present condition ($M = .74$) than the handouts absent condition ($M = .725$), whereas performance on the short answer questions was higher in the handouts absent condition ($M = .61$) than the handouts present condition ($M = .59$). While neither of these differences reached statistical significance, they did provide additional motivation for examining a larger set of short answer questions in Experiment 2.

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We only examined performance in the 12-minute delay condition, as delay did not interact with the presence of handouts during the lectures in Experiment 1. The only other change was that subjects reviewed all of the lectures in Experiment 2, as hopefully most students do review the to-be-learned material before they are tested on it. In addition, predictions about desirable difficulties are stronger when subjects review the material. We manipulated how the review variable was instantiated; review was either self-paced (as in Study 1) or restricted to two minutes. The two minute condition was of interest to see what happened when subjects in the Handouts Absent condition were not allowed to review for extra time. The manipulation of review time was between-subjects so that the set-time of two minutes would not influence self-paced review times.

EXPERIMENT 2

Method

Participants

Thirty-four Duke University students participated in the study. Two subjects were excluded from the analyses because of strong science backgrounds. Thus, the data from 32 subjects will be presented here. Subjects received course credit or $20 for their participation.

Materials

All materials were the same as in Experiment 1, except for the test materials. That is, we used the same four physics clips, PowerPoint handouts and filler tasks. For each video, subjects either answered short-answer questions or recalled all they could about the lecture (see Appendix). Test format was manipulated within-subjects and counterbalanced across subjects.

Design

The study had a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Review with handouts: Self-paced or 2 minutes) x 2 (Test format: Short answer or Free recall) mixed design. Review condition was the only between-subjects manipulation. Dependent measures were performance on final tests, and amount of notes written during lecture and review.

Procedure

Lecture viewing was identical to Experiment 1. After completing a brief filler task, subjects reviewed all four lectures (in contrast to Experiment 1, in which only two lectures were reviewed). In Experiment 2, review always began 12 minutes after the end of the lectures (unlike Experiment 1, in which half of the subjects reviewed after a 1-week delay). One-half of subjects reviewed the content of each lecture for 2 minutes and one-half reviewed the material at their own pace. Twelve minutes after the final review period, all subjects were tested on the lecture content. The test phase was the same except for the changed materials; for each lecture, subjects either recalled as much of the lecture content as they could, or answered eight short-answer questions (and assignment of lectures to test condition was counterbalanced across subjects). For lectures that were recalled, the format of the instructions was as follows: ‘Please type in the space below everything you

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remember about the lecture on DNA. You can imagine this is like a class exam—you will score better the more you can remember'.

Results

Lecture behaviour

As in Experiment 1, note-taking behaviour depended on whether or not handouts of the PowerPoint slides were available during the video lecture. That is, a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Review with handouts: Self-paced or 2 minutes) x 2 (Test format: Short answer or Free recall) ANOVA on number of words written during lecture yielded only a significant main effect of whether the handouts were available, $F(130) = 17.07$, $MSE = 2612.70$, $\eta_p^2 = .36$. When PowerPoint slide handouts were present during lecture, the lecture notes contained fewer words ($M = 55.6$) than when the slides were distributed after the lecture ($M = 92.9$).

When the handouts were unavailable during lecture, subjects tended to copy down much more slide information, instead of notes that elaborated on the lecture. Slide information was again defined as repeating exact words from the slides and words that were synonymous with ideas from the slides, and two coders counted the number of words reflecting slide content. Because the counts were highly correlated ($r = .97$), the counts were averaged for analysis. The prior analysis was re-done with content (slide versus non-slide) added as a factor, yielding a 2 (Content: Slide or Non-slide) x 2 (Presence of handouts during lecture: Present or Absent) x 2 (Review with handouts: Self-paced or 2 minutes) x 2 (Test format: Short answer or Free recall) ANOVA. In addition to the main effect of handout condition, the interaction between handout condition and content was significant, $F(130) = 9.51$, $MSE = 902.17$, $\eta_p^2 = .24$. When subjects viewed lectures without handouts, they wrote down many more *slide* words ($M = 54.6$) than they did when they viewed lectures with the handouts present ($M = 24.4$), $t(31) = 2.78$, $t(31) = 2.78$, $SEM = 5.86$. However, subjects did not take any more notes on non-slide content for the two lectures for which they had the handouts present; in fact, on average they recorded seven fewer non-slide words than did subjects in the Handouts Absent condition, $t(31) = 2.44$, $SEM = 7.66$. Overall, as in Experiment 1, the difference in quantity of notes taken was driven predominately by the need to copy the slide material when handouts were unavailable.

Review behaviour

As in Experiment 1, few words were written in the red pen during the review period ($M = 2.88$ words). Given that 23 subjects (72%) did not write a single word during review, no further analysis of review notes was conducted. In contrast to Experiment 1, the 16 subjects in the self-paced review condition did not show any difference in review time in Experiment 2 ($M = 2.42$) as a function of handout condition $F(115) = 1.25$, $MSE = .8$, $p > .2$, $\eta_p^2 = .08$.

Test performance

Short-answer responses were stored as text files marked only with subject number, and were scored in the same way as in Experiment 1: two trained (and condition-blind) undergraduate coders scored each short-answer response, and awarded 1 point per correct answer, ½ point for a partially correct answer, and no points for an error. The coders' scores were correlated ($r = .77$), and again we used a third coder (the second author, who was also

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blind to experimental condition) to resolve all discrepancies. Thus the analyses that follow involve the proportion of the eight short-answer questions answered correctly.

Free recall protocols were also stored as text files marked only with subject number. To score them, a master list of facts was created for each of the four videos. On average, each video excerpt contained 36 facts. Two trained coders who were blind to experimental condition scored each free recall protocol; for each fact, they decided if it was included in the free recall protocol or not. Before scoring real data, each coder worked through multiple samples and received feedback on their scoring. This procedure yielded good agreement between coders; the coders generated free recall scores that were highly correlated ($r = .98$) and a third condition-blind coder resolved all discrepancies.

As shown in Table 2, test performance depended on whether or not handouts of the slides had been available during the lecture. That is, a 2 (Presence of handouts during lecture: Present or Absent) x 2 (Review with Handouts: 2 minutes or Self-paced) x 2 (Test format: Short answer or Free recall) ANOVA on proportion correctly revealed a main effect of handout availability, $F(130) = 9.34$, $MSE = .01$, $\eta_p^2 = .24$. Test scores were higher for lectures watched *with* printouts of the slides ($M = 0.45$) than for lectures watched *without* paper handouts ($M = 0.41$).

Not surprisingly, two other main effects were significant. First, scores were higher on short-answer tests ($M = 0.61$) than on free recall tests ($M = 0.25$), $F(130) = 118.23$, $MSE = 0.04$, $\eta_p^2 = .80$, although this result must be interpreted with some caution as is the case with any comparison between two different dependent measures. Second, the main effect of review time was also significant, $F(130) = 6.19$, $MSE = .10$, $\eta_p^2 = .17$. Subjects who had no limit on review time (and who studied on average 2.42 minutes) performed better ($M = 0.50$) than those who were limited to 2 minutes of review time per lecture ($M = 0.36$).

Although no other interactions reached traditional levels of significance, an examination of Table 2 suggests that the memorial consequences of having encoded the lecture with handouts depended on the nature of the final test, $F(130) = 2.33$, $MSE = .02$, $p = .138$, $\eta_p^2 = .07$. Directed analyses supported that having had the handouts during lecture led to better performance on short-answer questions, as compared to encoding without the handouts, $t(31) = 2.67$, $SEM = .03$, $p < .02$. But, the presence or absence of handouts during lecture had no impact on later free recall of the lecture ($t < 1$).

Table 2. Test performance, as a function of whether handouts of presentation slides were present during lecture, review condition and type of test. Data are from Experiment 2

		Presence of Handouts (during Lecture)		
Final test	Review time	Handouts Present	Handouts Absent	*M*
Short Answer				
	Self-paced	0.73	0.66	0.70
	2 minutes	0.56	0.48	0.52
	M	0.65	0.57	
Free Recall				
	Self-paced	0.29	0.31	0.30
	2 minutes	0.21	0.18	0.20
	M	0.25	0.24	

Note. The standard error was 0.03 for both short answers and free recall.

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Discussion of experiment 2

Replicating the first experiment, watching a lecture with a handout of the PowerPoint slides affected note-taking. For lectures unaccompanied by handouts, subjects took more notes in order to copy down the slide material as the slides were presented. However, in contrast to the first study, performance on the final test depended upon whether the handouts had been available during lecture. Subjects performed better on the final tests corresponding to lectures viewed with handouts. In this experiment, not only did encoding with handouts ease note-taking, it also led to a benefit on the final tests. In particular, that benefit was observed on the short-answer questions.

Why would the presence of handouts during lecture lead to memorial benefits in Experiment 2 but not Experiment 1? One important difference between the two experiments involved the self-paced review times. In Experiment 1, subjects spent less time reviewing lectures they had viewed with handouts than lectures viewed without handouts. In contrast, in Experiment 2, review times did not differ as a function of whether handouts had been available during encoding. Thus one possibility is that the extra time spent reviewing lectures in the Handouts Absent condition compensated for their difficulty in Experiment 1 (Nelson, 1993). Of course this analysis does not explain why the presence of handouts affected review time in Experiment 1 but not Experiment 2, but subjects' allocation of study time is not always optimal (e.g. Nelson & Leonesio, 1988).

GENERAL DISCUSSION

When surveyed students saw examples of the physics slides we used in the experiments, they indicated a preference for receiving them *prior* to lecture. They justified this preference with the claim that it would reduce the burden of note-taking. In this case, the students' intuitions were correct: access to handouts of the PowerPoint slides during lecture reduced note-taking (Experiments 1 and 2), primarily because students no longer copied down the text appearing on the slides. These results are consistent with the Efficient Encoding Hypothesis: having access to handouts made encoding more efficient in the sense that the need to take notes was reduced. It was less clear, however, that releasing students from the burden of note-taking yielded increased attention to and encoding of the lecture; there was no increase in elaborative (non-slide) note-taking in the Handouts Present conditions of either experiment. This might change with different materials; for example, subjects might be more likely to elaborate on very complex subject matter, or on terse slides that did not contain enough information to be understandable on their own. Another possibility for future research is whether students might benefit from explicit instruction about what to do during note-taking, beyond simply copying the slides. Both of these scenarios are ones in which the benefits of having the handouts during lecture might be greater than what we observed here.

The memorial consequences of this efficient encoding were less consistent across the two experiments. In Experiment 1, the more efficient encoding in the Handouts Present condition led to similar performance on both immediate and delayed tests as observed in the Handouts Absent condition. In Experiment 2, compared to the Handouts Absent condition, more efficient encoding (in the Handouts Present condition) led to improved performance on an immediate short-answer test but to similar performance on an

immediate free recall test. Thus an obvious direction for future research is to understand how any memorial benefits of handout presence may depend upon the format of the final test; the data reported here represent only a first step and do not resolve this issue. In no case, however, did having had the handouts during lecture impair performance on the final tests. Even when there were no differences in final test performance, students still benefited in the sense that they reached the same level of learning with less work.

There was no evidence that additional note-taking yielded memorial benefits; final test performance in the Handouts After condition was sometimes similar to that observed in the Handouts Present condition, and sometimes lower. The fact that subjects could review the handouts after the fact meant that any benefit from note-taking had to be in the act of writing itself, since the review period meant subjects had the full information available to review. Copying the slides appeared unlikely to be a deep encoding task, and instead may have reduced the note-taker's ability to listen to the instructor. While copying slide information may have been helpful if the slides had *never* been given to the students, our survey of instructors suggests that is an unlikely scenario. Rather, a more fruitful direction for future research might involve examining longer delays as encountered over the course of an academic term (which would be more likely to show any benefits of desirable difficulties), and whether note-taking has any other benefits, such as keeping the student focused and preventing mind-wandering (e.g. Kane, Brown, McVay, Silvia, Myin-Germeys, & Kwapil, 2007).

Mayer and Moreno (2003) argued that students have limited capacity to encode incoming information, and that care must be taken with multimedia learning to avoid overloading the learner. That is, the temptation with new technology is often to give students *more*, with the assumption that more is better. For example, it is easy to imagine the PowerPoint lecturer adding colour or pictures to their lectures because it is much easier to do in PowerPoint than with overhead transparencies. Today's technology enables the teacher to animate slides and embed videos within PowerPoint, and to move along at a brisk pace (with no chalkboard slowing the teacher down to the note-takers' speed of writing). In Mayer and Moreno's (2003) terms, a visual overload results from the need to alternate looking at the screen and at one's notes, and a more general overload results from listening to the instructor's words and writing notes. The solution is to free up some capacity; in this case, cognitive resources can be freed by releasing students from copying the slides.

We used relatively simple science materials, short lectures and non-science majors who were presumably unfamiliar with the lecture topics. With different materials and subjects, the results might differ. However, in situations where students' notes are likely to reiterate the content of the slides, there is no harm from releasing students from note-taking.

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APPENDIX

Experiment 1: sample test questions

Multiple-choice:

Which color is the eye best at distinguishing?

a. blue
b. green
c. red
d. yellow

Short answer:

Describe and explain phosphorescence:

Experiment 2: sample test questions

Short answer:

Describe the spectrum of visible light. Explain the energy levels, wavelengths and give examples of rays at various ends of the spectrum.

Free recall:

Please type in the space below everything you remember about the lecture on Seeing the Subatomic. You can imagine this is like a class exam - you will score better the more you can remember.

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